

Electrical Modeling of PV Plants in Bulk System Studies

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SYSTEMS INTEGRATION

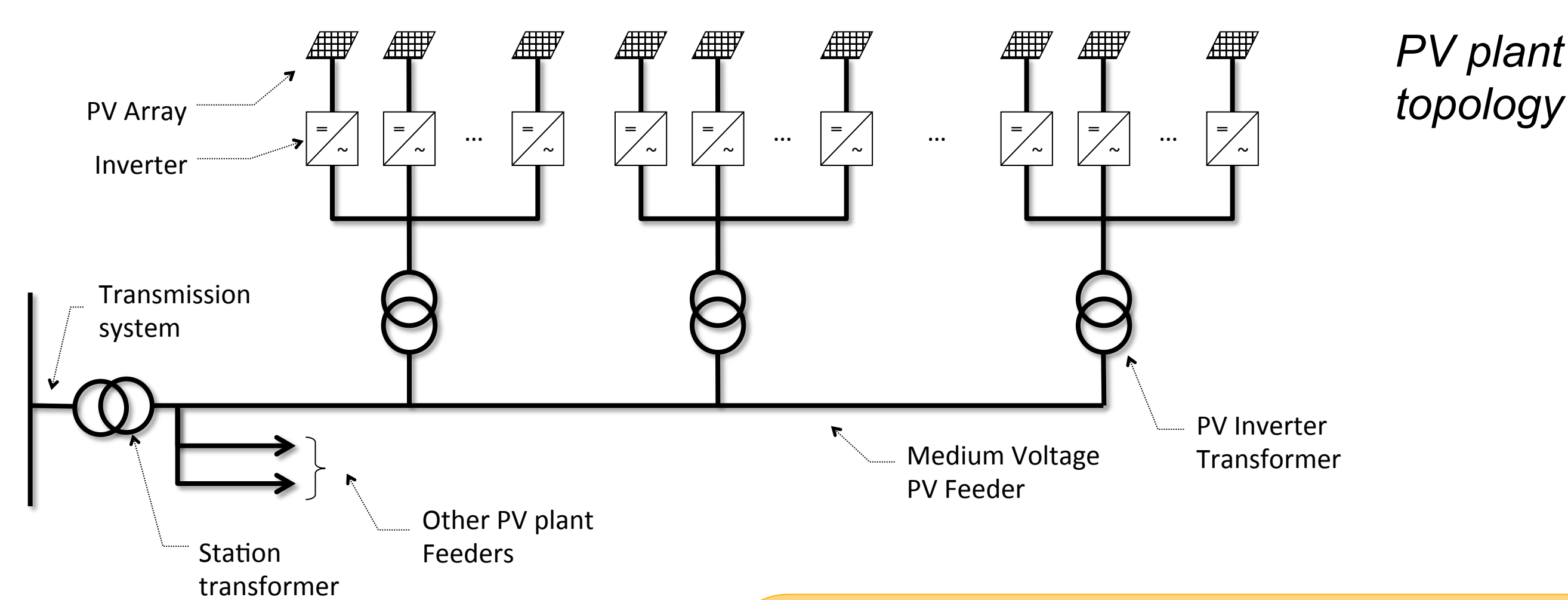
OVERVIEW

Simulations are used to assess transmission system reliability and determine grid upgrades needed to interconnect new generation. PV modeling has not been standardized. Addressing this gap will greatly facilitate the study process and will help preserve grid reliability.

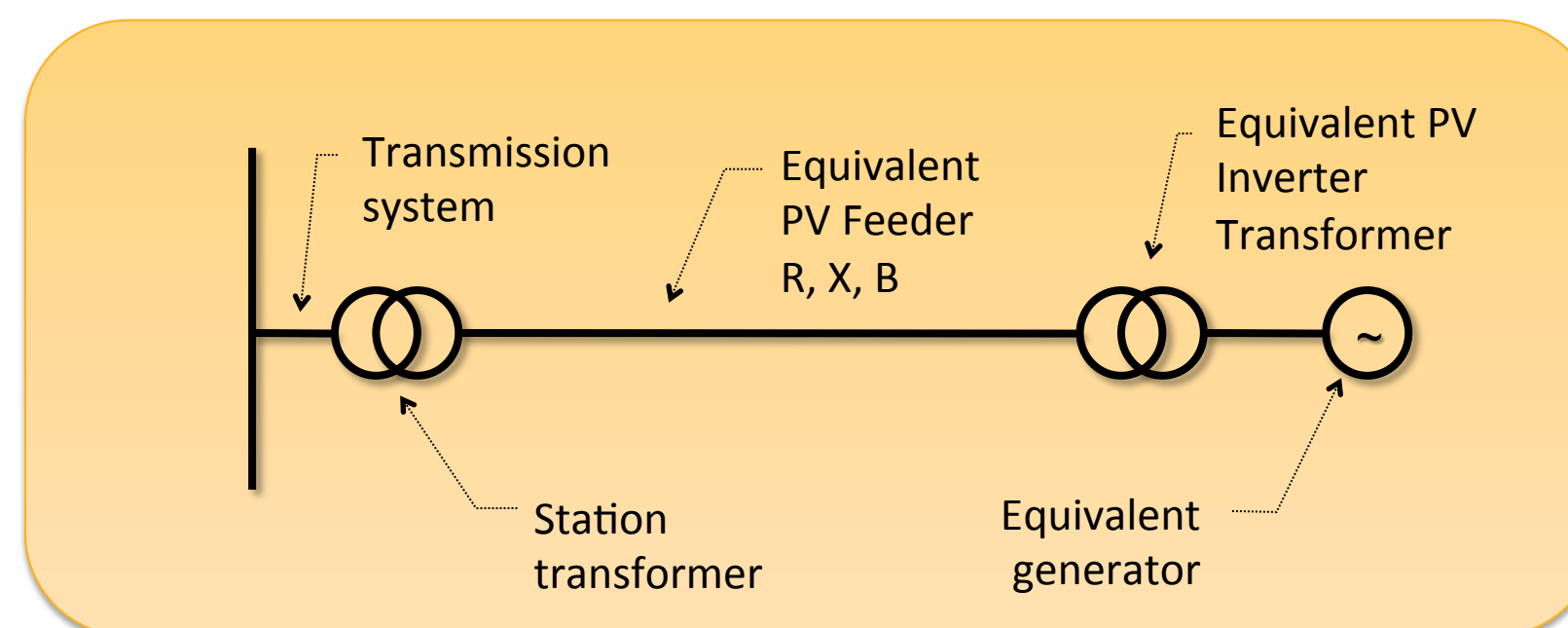
Sandia coordinates the development of standard *power flow*, *short circuit* and *dynamic models* for solar generation, under the Renewable Energy Modeling Task Force (REMTF) of the Western Electricity Coordinating Council (WECC).

POWER FLOW REPRESENTATION

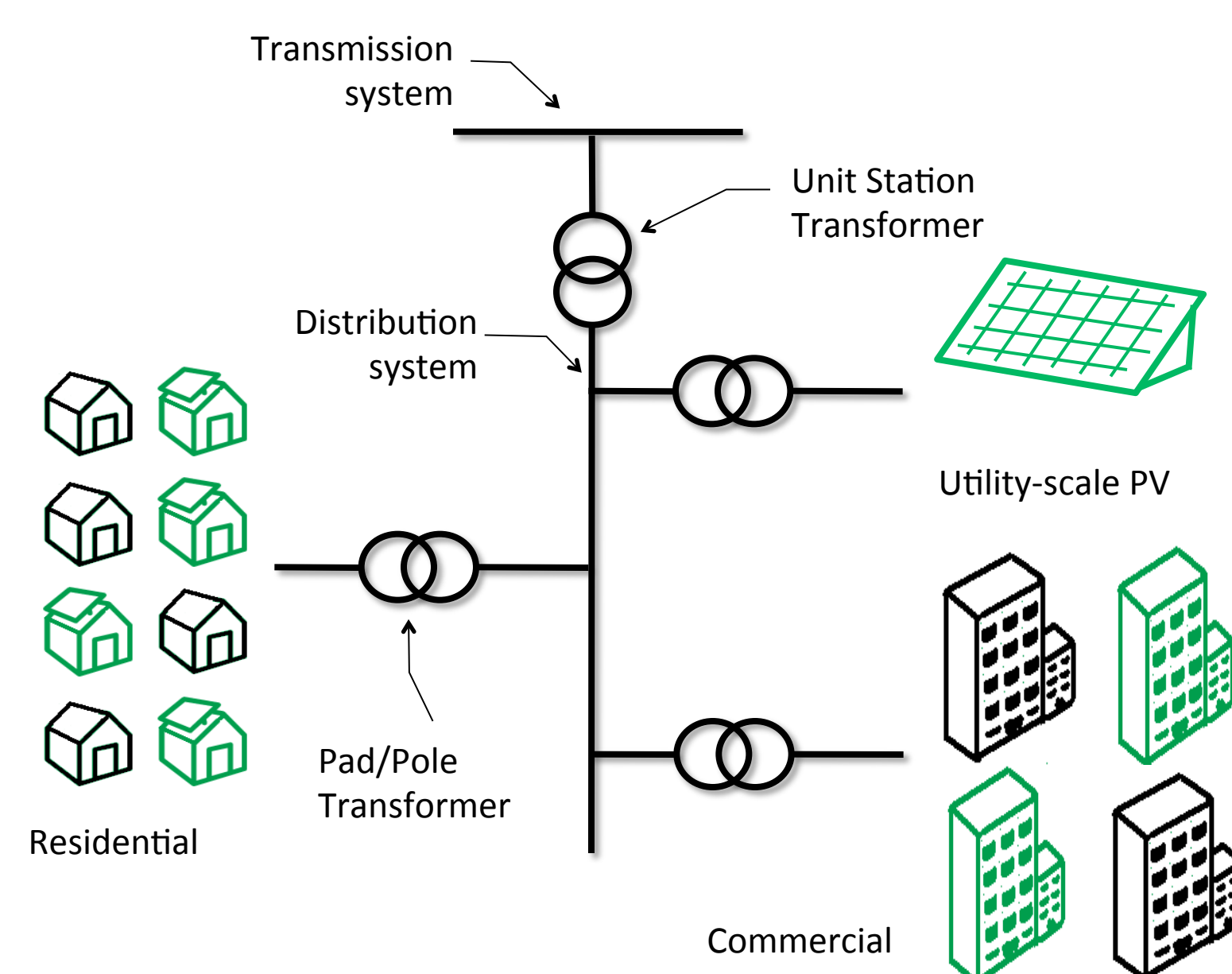
For practical reasons, PV plants are modeled as a single-generator equivalent, and distribution-connected PV are aggregated at the transmission bus.



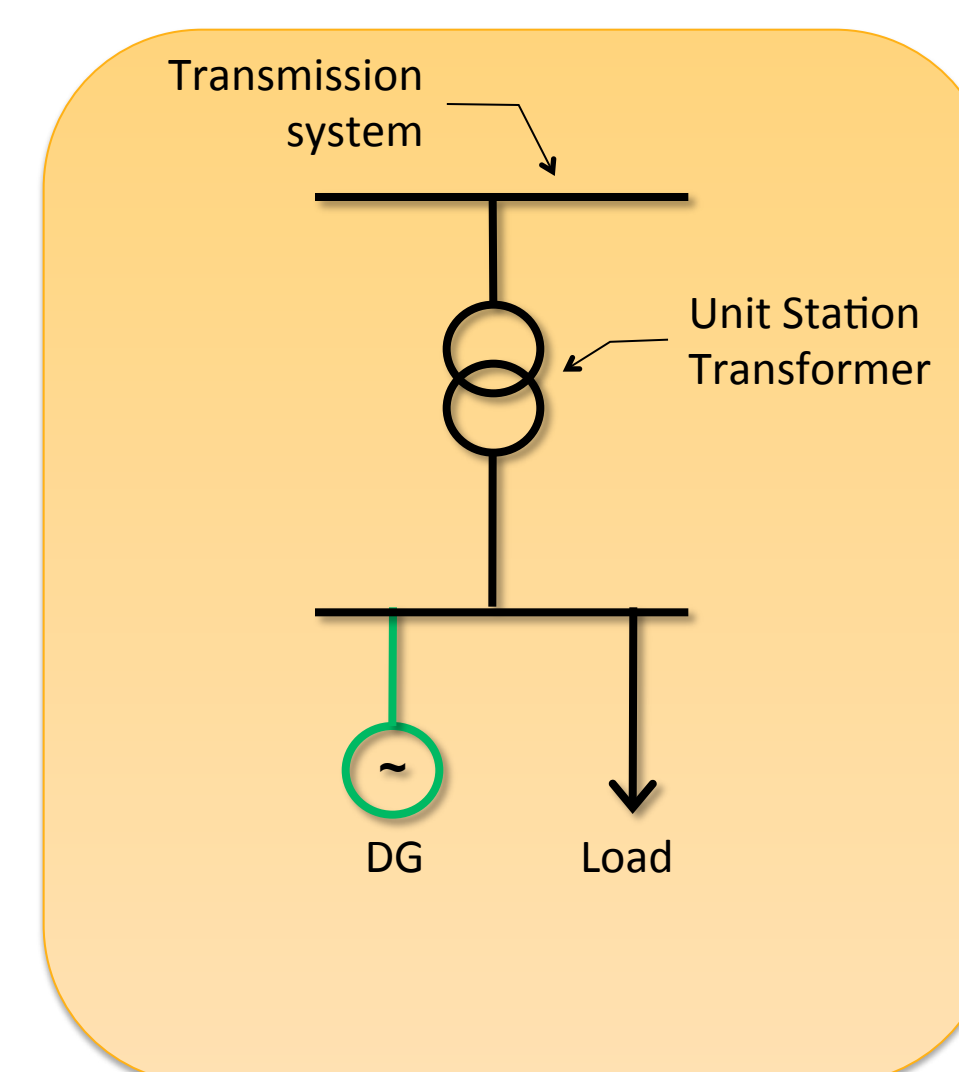
Single-machine equivalent representation



Distribution-connected PV



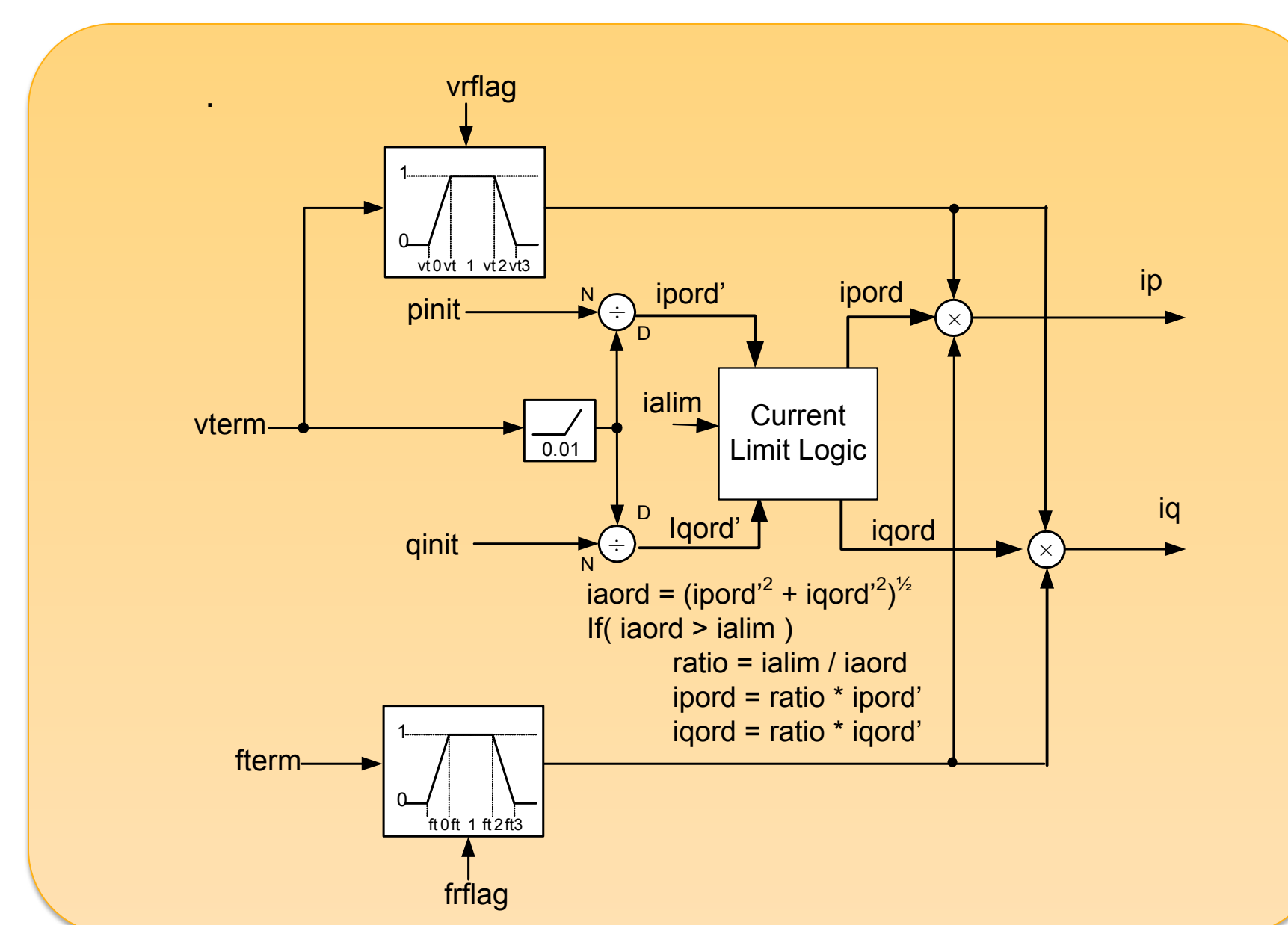
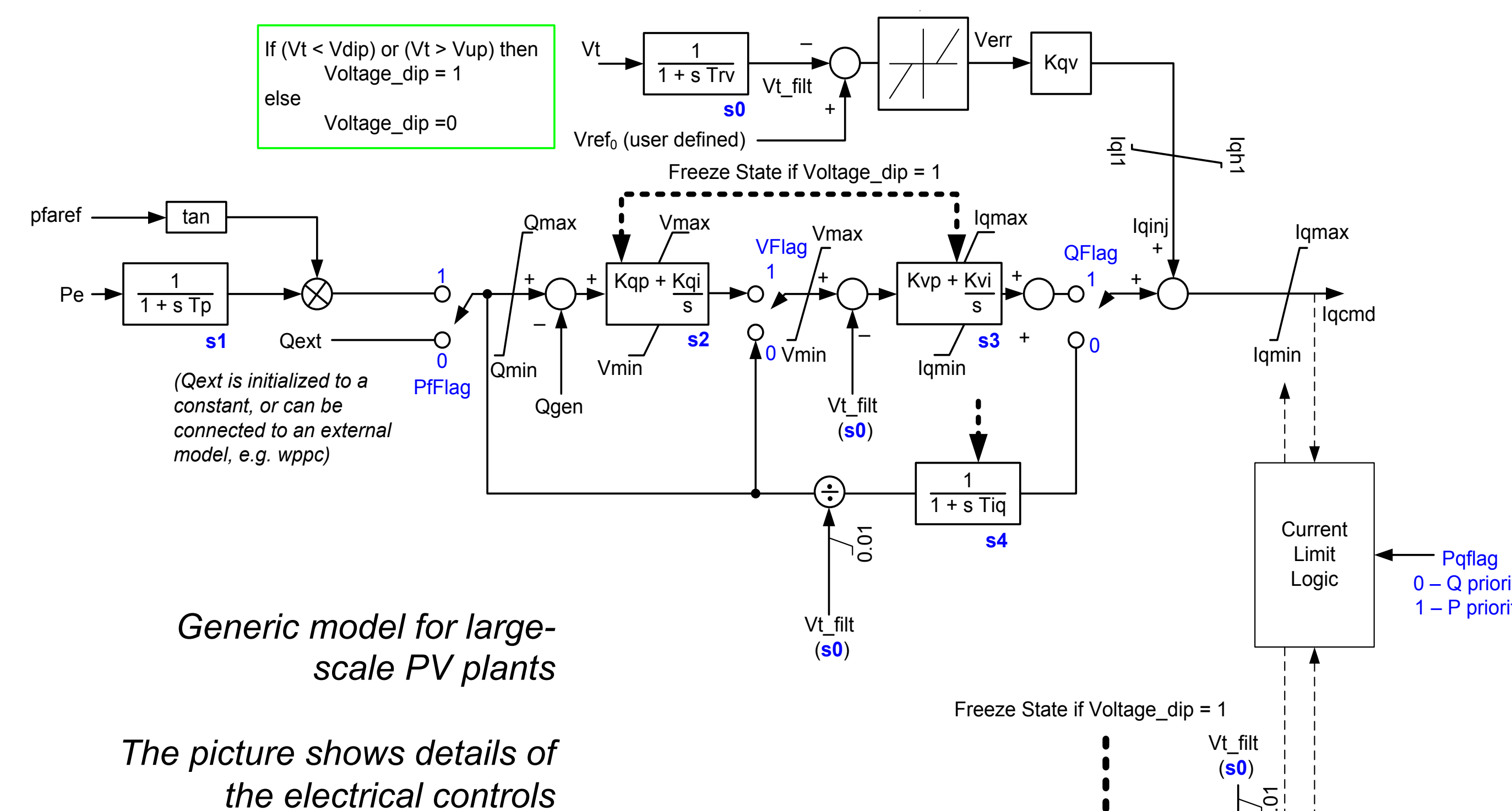
Aggregated representation



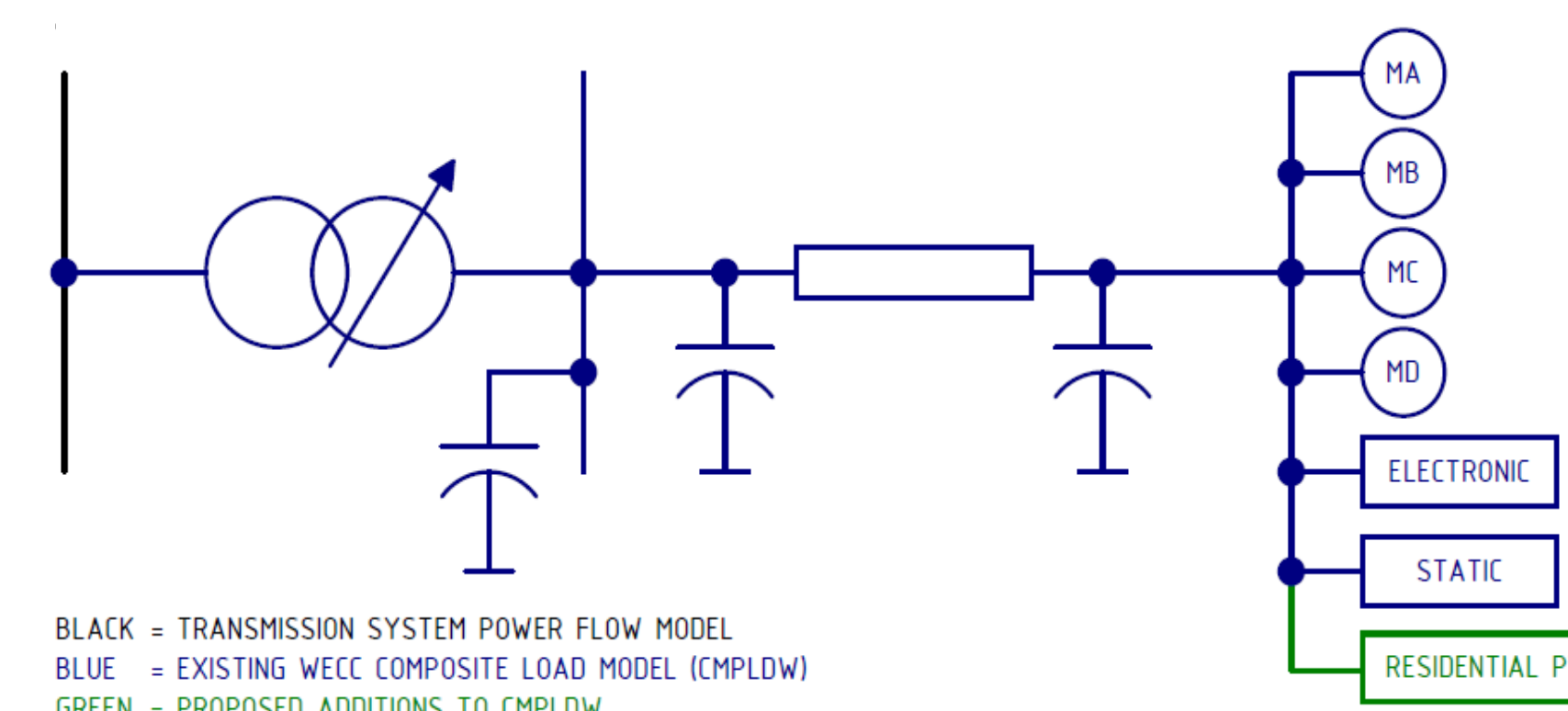
DYNAMIC REPRESENTATION

Generic models approximate the dynamic behavior of PV plants during grid disturbances without the need for manufacturer-proprietary information. Model parameters are adjusted to account for different controls.

- ❖ PV plant models include protection features, active and reactive control options implemented in the inverter controls, or in the PV plant controller.
- ❖ Distributed PV models include the effect of electrical separation, voltage and frequency trip thresholds, and inverter current limits.



Composite Load Model with PV generation

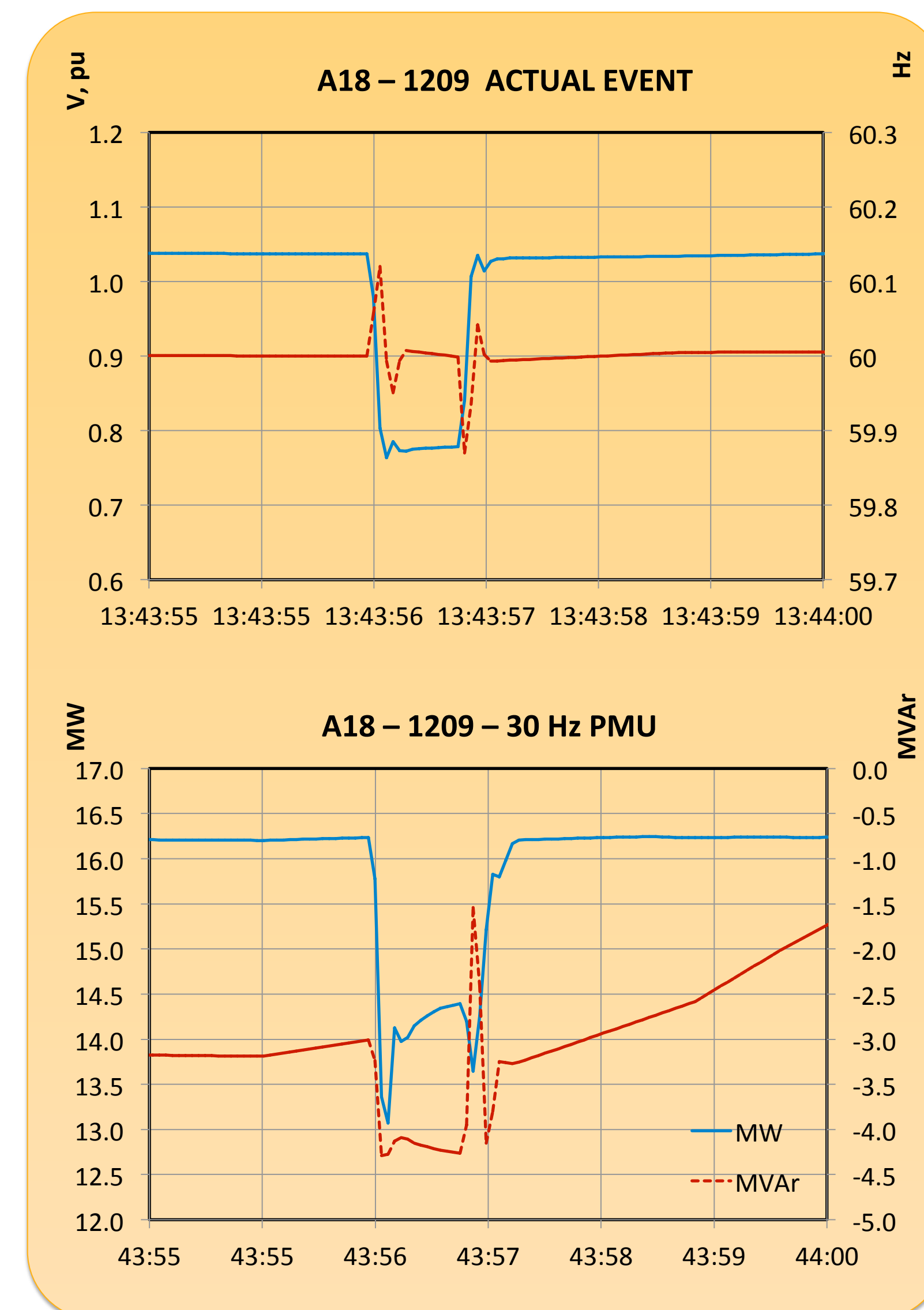


MODEL VALIDATION AND IMPLEMENTATION

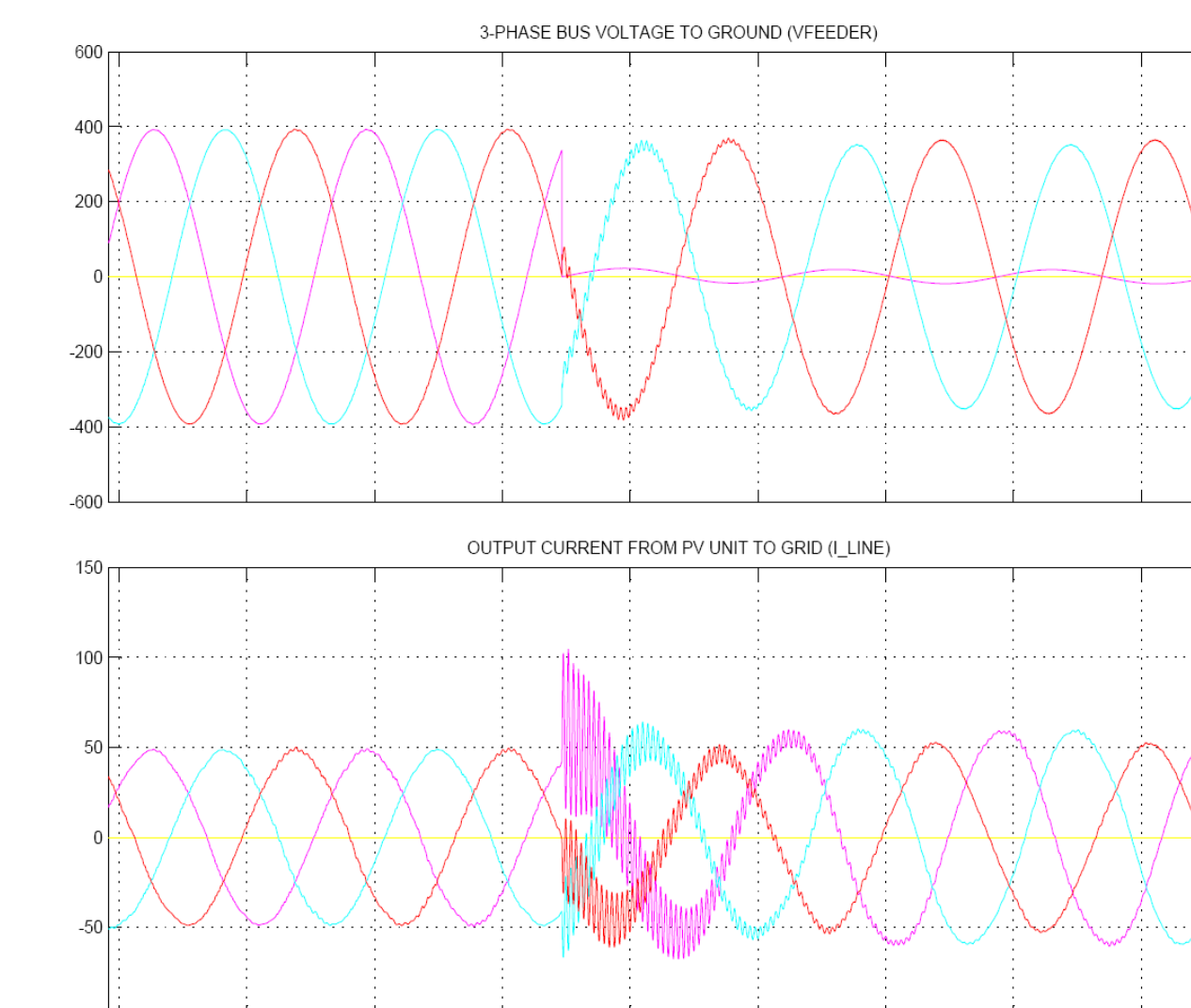
Model validation is conducted against lab test and field data from multi-MW PV plants, using Phasor Measurement Units (PMUs).

Sample PV plant data for model validation

REMTF models are being implemented in commercial simulation software



SHORT CIRCUIT REPRESENTATION



- ❖ Plant output during grid faults is highly dependent on inverter controls, transformer connection and collector system design.
- ❖ This behavior cannot be simulated without vendor-specific and detailed transient models.

Example of PV inverter transient behavior following a short circuit event

OUTLOOK

- ❖ Model development for PV plants is a collaborative effort that involves manufacturers, software developers, model users, and reliability entities.
- ❖ REMTF leads technical activities on solar modeling. Currently, generic dynamic models are in the validation phase.